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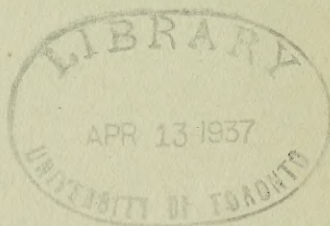
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PHYSICAL SCIENCE SERIES

No. 7 Papers from the physical laboratories

No. 3 ON THE RADIOACTIVITY OF METALS
GENERALLY,

BY J. C. McLENNAN AND E. F. BURTON.



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ON THE RADIOACTIVITY OF METALS GENERALLY

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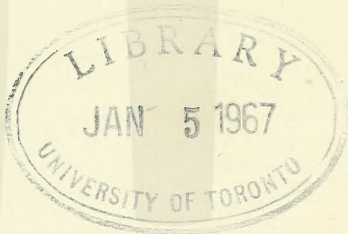
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ON THE RADIOACTIVITY OF METALS GENERALLY*

Introduction. In a former paper by the authors¹ on the conductivity of a mass of ordinary air confined within a large metallic receiver it was shown that about 37 per cent. of the conductivity was due to an exceedingly penetrating radiation which, traversing the air in the room, passed through the walls of the receiver. It was also shown that the conductivity of fresh atmospheric air, after being confined in a metallic cylinder, rapidly fell to a minimum value, that a gradual rise then took place, and that a steady state was reached after some hours.

On account of the known decay of the constituent in atmospheric air responsible for excited radioactivity, the fall in the initial conductivity was attributed to its presence in the cylinder, and the subsequent rise to an emanation of a similar character given off by the walls of the containing vessel; the steady state representing a condition of equilibrium, where the rate of decay of this emanation was equal to the rate at which it was produced.

It was also pointed out that the limiting value of the conductivity thus reached varied with the metals forming the walls of the receiver. In experiments with lead, tin and zinc the conductivity was highest with lead and lowest with zinc. In view of these results, and on account of the known complex character of the radiation from such highly radioactive substances as radium and thorium, a series of experiments was made to investigate still further the radioactivity of ordinary metals.

As a result of these experiments, we find that when a cylinder of any metal is enclosed within a second of the same material, insulated from it, and surrounded by air or other gases, it gradually acquires a negative charge, and after a short time reaches a state of equilibrium at a definite potential below that of the enclosing cylinder.

* Read before the Royal Society of Canada, May 18, 1903.

¹ Phys. Review, Vol. XVI., No. 3, p. 184, 1903, and University of Toronto Studies, Physical Science Series No. 2.

So far the experiments made indicate that the negative charge acquired by the cylinder results from a process in which an excess of positively charged corpuscles is expelled from its surface. This process is probably identical with the α radiation observed by Rutherford¹ and others in the highly radioactive substances radium, thorium and uranium, and experiments are now being made by the writers to determine its relation to the effect observed by Guthrie² and developed by Elster and Geitel,³ J. J. Thomson,⁴ Richardson,⁵ Strutt⁶ and others, that a metal, platinum for example, when heated to a dull red will discharge a negatively charged body placed near it, but not one positively charged.

Experiments—Metal Effect. In these experiments cylinders of aluminium, zinc, lead, tin and copper were used, the outer ones being 120 cms. in length and 24 cms. in diameter, and the inner 110 cms. in length and 19 cms. in diameter. The measurements were made with a quadrant electrometer whose sensitiveness was such as to give a deflection of 1,000 mms. on a scale situated at one metre from the needle for a potential of one volt.

The apparatus and its connections are shown in Fig. I., where A and B represent the cylinders of the metal examined. The wire which led from the inner cylinder to the electrometer was of brass and was surrounded by a tube of the same metal to screen off induction effects. This tube, as well as the outer cylinder B and the metallic screen over the electrometer, was kept joined to earth during an experiment. The inner cylinder and the free quadrants were earthed by means of the brass rod D, which carried a platinum tip and made contact with a small platinum plate attached to the connecting wire as shown in the figure. The tube was provided with a small opening so arranged that the withdrawal of the rod D did not effect the capacity of

¹ Phil. Mag., Feb., 1903, p. 177.

² Phil. Mag. [4] 46, p. 257, 1873.

³ Wied. Ann., 38, p. 27, 1889.

⁴ Phil. Mag., XLIV, 1897, p. 203.

⁵ Proc. Camb., Phil. Soc., XI, p. 286.

⁶ Phil. Mag., Vol. IV, Sixth Series, 1902, p. 98.

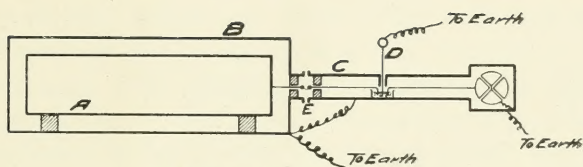


Fig. 1.

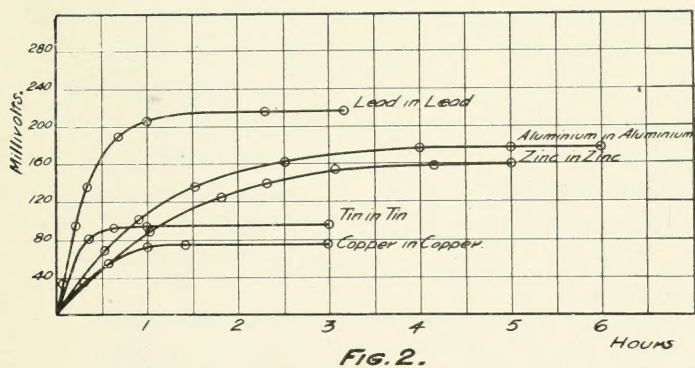


Fig. 2.

the system. Plugs and supports of paraffin wax provided insulation for the apparatus.

In making a measurement the connecting rod D was withdrawn and the apparatus left intact. The inner cylinder B and the free quadrants then slowly acquired a negative charge which finally reached a limiting value. This value varied with the metal used in the construction of the cylinders A and B, but did not vary with samples of the same metal obtained from different sources. It was also the same whether the needle of the electrometer was positively or negatively charged. With lead, tin and copper the limiting value was reached in about one hour, but with aluminium and zinc not before four or five hours had elapsed.

Readings for pairs of cylinders of these metals at 16°C are set forth in Fig. II., where curves are drawn with the time expressed in hours for abscissæ and the negative potential attained by the inner cylinder expressed in millivolts for ordinates. The limiting values for the different metals are as follows :

	Millivolts.
Aluminium.....	178
Zinc.....	160
Lead.....	216
Tin.....	95
Copper.....	73

In experimenting with lead cylinders the pressure of the air in B was reduced from 750 mms. to 20 mms. of mercury and a slight drop in the limiting potential of about three or four per cent. was observed.

Measurements were also made with different gases at atmospheric pressure between these cylinders, and it was found that the limiting potential slightly increased with the density of the gas used. A set of readings taken with hydrogen, air, oxygen and carbon dioxide is as follows :

	Millivolts.
Hydrogen.....	205
Air.....	216
Oxygen.....	220
Carbon Dioxide.....	233

Experiments were also made with lead by varying the diameter of the inner cylinder. With cylinders 19, 13 and 4 cms. in diameter respectively no difference was observed in the limiting

potential, but the time required to reach it slightly increased with the use of cylinders of smaller diameter.

The experiments were also varied by placing the lead cylinders in a tank filled with water, the surrounding layer of water having a thickness of 13 cms. Under these conditions the limiting potential was found to be unchanged.

It was also observed that this metal effect was produced when Röntgen or Becquerel rays were allowed to traverse the cylinders. With these radiations, however, the limiting negative potentials were reached in the course of a few seconds and varied but little from the values obtained for the different metals under ordinary conditions. A small quantity of radium chloride of activity 1,000 confined in a glass phial was used as the source of Becquerel rays, and was placed, in the experiment, on a support close to the outside of the cylinder B. The effect was also produced with a quantity of uranium oxide placed near the cylinder, but a much longer time was required than with the radium to reach the steady state.

The following are the values of the limiting negative potentials obtained under the different conditions :—

METAL	Negative Potential in Millivolts		
	Natural Radiation.	Röntgen Rays.	Becquerel Rays.
Aluminium.....	179	179	179
Zinc.....	160	176	180
Lead.....	216	175	201
Tin.....	95	98	100
Copper.....	73	72	69

Volta Effect. It is evident that, with cylinders of different metals, the arrangement shown in Fig. 1 afforded a means of exhibiting the Volta effect and of approximating to a measure of the contact differences of potential for a series of metals.

With the rod D in position a difference of potential would exist between the cylinders A and B. Its withdrawal would be followed by a gradual equalization of these potentials which would result in a charge being communicated to the connecting wire and the free quadrants. This again would set up a current

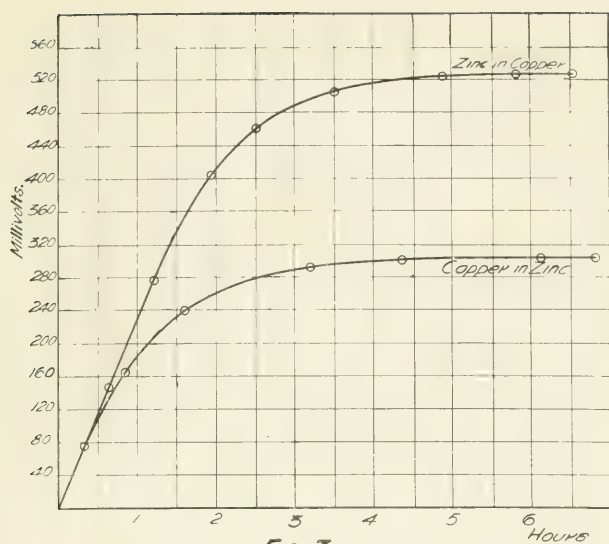


FIG. 3.

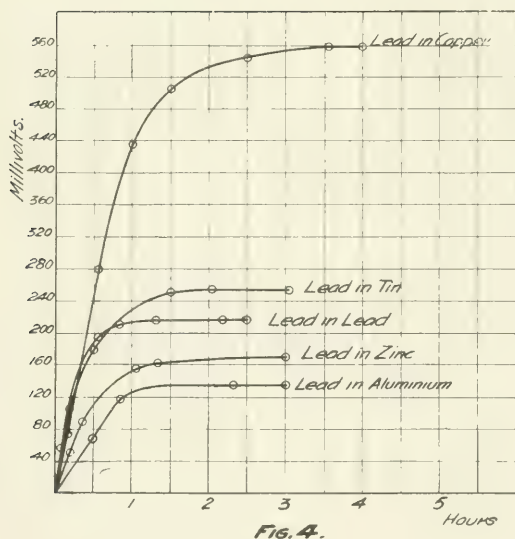


FIG. 4.

to the surrounding tube C, and finally the free quadrants would attain a steady potential, the current between the cylinders being equal to that between the connecting wire and its surrounding tube. The potential assumed by the free quadrants under these circumstances, while approximating to, would be less than the contact difference of potential for the metals used in the two cylinders.

The values obtained in this way for any two given metals, while differing in sign, should be numerically the same, whichever metal was used for the inner or outer cylinder. But on trial with a number of pairs of metals, it was invariably found that the readings differed when an interchange was made of the metals in the cylinders. This is illustrated by the curves in Fig. III., which give the results for the metals zinc and copper, the upper representing the negative potentials acquired by the quadrants with an inner cylinder of zinc, and the lower the positive potentials with one of copper. The final potentials, it will be seen, are 527 and 304 millivolts respectively.

This result finds its explanation in the metal effect described above. We have shown that, with zinc cylinders, the inner, in virtue of this effect, attains a potential of 160 millivolts below that of the outer, while with copper the corresponding value is 73 millivolts. If then we suppose the two "effects" to act concurrently, the final readings observed with the zinc and copper cylinders will represent their algebraic sum. Denoting the metal effect for zinc by x and that for copper by y and the Volta effect for the two metals by V , we have

	Limiting Potential (millivolts)
$V + x =$	527
$V - y =$	304
$x =$	160
$y =$	73

from which we obtain the values 367 and 377 millivolts for the contact difference of potential for the metals zinc and copper, an agreement sufficiently close to confirm our hypothesis.

Similar measurements have been made with all combinations of the metals aluminium, zinc, lead, tin and copper, taken in pairs, with uniformly close results, the volta effects obtained

in this way being in every case proportionately less than the generally accepted values.

As an additional illustration of these measurements, the curves representing the results obtained with an inner cylinder of lead and an outer of each of the metals are shewn in Fig. IV. Combining the limiting potentials of these with the metal effect for lead, 216 millivolts, the potential differences for the different pairs of metals are as follows:—

		Difference of Potential (millivolts)
Aluminium	}	
Zinc		35
Lead		45
Tin		37
Copper		306

values which are considerably below those generally adopted.

Conclusions. The gas between the two cylinders always contains a number of ions, and, on account of the greater rate of diffusion of the negative ions, it is possible that an excess of these would impinge upon the inner cylinder in a given time and thus leave it negatively charged. The resulting potential, however, should be the same for all metals on this hypothesis.

Again, it is possible that the very penetrating radiation which is present in ordinary air may consist of negatively charged matter and that the negative charge taken up by the inner cylinder represents the amount of this radiation intercepted by it. But the high value obtained for aluminium, together with the results obtained with Röntgen rays, is against this conclusion.

It seems rather that a process is going on at the surface of the metal, whereby an excess of positively charged corpuscles is being continually emitted, and that the steady state attained represents a condition of equilibrium in which the current between the cylinders is equal to rate of efflux of the positive charges.

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